IGSI

UNIT - 4

CHEMISTRY FOR CLASS IX

STRUCTURE OF ATOM

राष्ट्रीय शैक्षिक अनुसंधान और प्रशिक्षण परिषद्

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PREFACE

The present series of twelve chemistry units has been developed for try-out of the Individually Guided System of Instruction (IGSI) in class IX The description of IGSI and first two units of this series of units are available under a separate cover. This new system of instruction and the units have been developed along the lines of the National Policy on Education (NPE-86) and involve the participation of pupils in the process of learning. The units are suited for self-study with occasional help from a tutor. In the present context, these-units will serve an examplar self-study material for secondary stage chemistry. In developing this unit, I was assisted by some of the chemistry teachers.

This unit contains an introduction for motivation, arousing interest, and to link the present unit with preceding and next units. The objectives given in this unit are the expected learning outcomes, so that the pupil will know the ultimate goals he has to achieve. The suggested reading material provided in the unit guides the pupil to achieve pre-stated objectives. A number of intext and post-text questions, activities, and problems have been included to provide enough practice and chance for self evaluation.

The suggestions for the improvement of this unit will be welcomed.

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March, 1988

I Introduction

Everything around us — food, clothes, paper, pen, furniture, etc. — is made up of matter. We have already studied in unit - 1 that matter is composed of tiny particles, known as atoms. Therefore atoms are the basic building units of all kinds of matter. The properties of matter depend upon (a) the nature of atoms constituting it and (b) the nature of linkages between the various atoms. In order to understand properties of matter and various aspects of chemistry, it is essential to fully understand the structure of these basic building units - that is atoms. In this unit we shall study about the sub-atomic particles and about the various models of atom proposed from time to time.

II. Objectives

After completing this unit, you should be able to :

1. Explain electrical nature of matter.
2. Describe the origin and properties of cathode rays and positive rays.
3. Compare the properties of sub-atomic particles i.e. electrons, protons and neutrons.
4. Describe various models of an atom on the basis of sub atomic particles.
5. Calculate the number of protons, neutrons and electrons using the values of atomic number and mass number.
6. Explain the term isotopes with examples.
7. Write electronic configuration of atoms of first 20 elements.
8. State the importance of valence electrons.
9. Predict the number of valence electrons in various atoms.

III. Suggested Reading Material

Electrical nature of matter

Carryout the following activities ;

1. Rub an inflated rubber balloon with dry hair or clothes. Does it stick to the Wall ?

2. Comb dry hair. Does the comb artract small pieces of paper ?

   From above activities we can conclude that after rubbing two articles with each other, they become electrically charged.

3. If you rub ebonite rod with fur of a cat, it gets negatively charged while the fur of cat becomes positively charged.

4. If you rub a glass-rod with a silk cloth, the rod gets positive charge and silky cloth becomes negatively charged.

These activities show that matter is electrical in nature and can produce positve or negative charge under different experimental conditions. Since the positive and negative charges in the matter are equal in magnitude, tne matter is neutral.

4.1.1 Origin of cathode rays

Sir J.J. Thomson took a discharge tube and filled it with a gas. He passed an electric discharge through this gas at a very low pressure (0.001 mm Hg). He found a greenish glow emitted from the cathode. This glow is made up of light rays emitted by cathode. The rays are known as cathode rays.

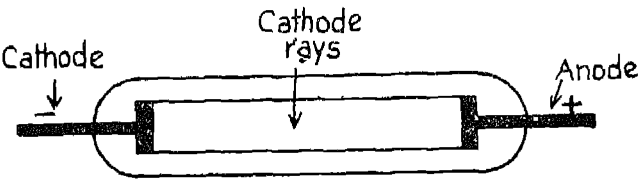

Fig. 4.1 Formation of cathode rays.

4.1.2 Characteristics of cathode rays

(i) Cathode rays travel in straight lines. If any object is placed in the path of the cathode-rays, it will cast a shadow of the object on the other end i.e. opposite to the cathode

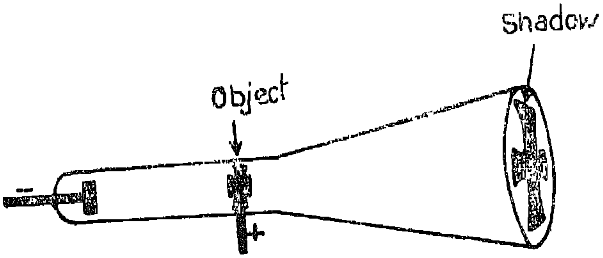

Fig. 4.2 Casting of shadow of an object.

(ii) Cathode rays consist of material particles and possess kinetic energy. If a light paddle is placed in the path of cathode rays, the paddle starts rotating. This indicates that cathode rays consist of a beam of material particles having kinetic energy as they are capable of producing machanical effect.

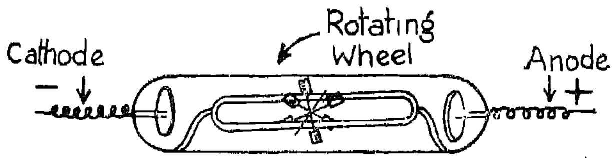

Fig. 4.3 Rotation of paddle wheel by cathode rays.

(iii) Cathode rays are negatively charged particles. Cathode rays are deflected when passed through an electrical or magnetic field. These rays are deflected towards positive plate in a strong

electric or magnetic field. This proves that cathode rays consist of negatively charged particles.

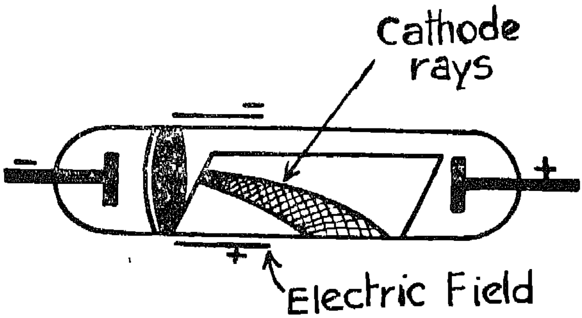

Fig. 4.4 Deflection of cathode rays in electric field.

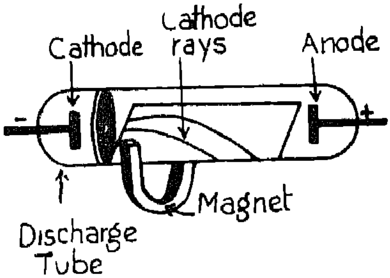

Fig. 4.5 Deflection of cathode rays in magnetic field

(iv) Due to their high kinetic energy due to high velocity ($KE=1/2\ mv^2$), these rays are capable of ionising the gas through which these are passed.

(v) They cause heating effect i.e. heat the object on which they fall.

(vi) They can produce X-rays when they fall on a solid like copper.

Thomson observed that whatever be the gas used in the discharge tube, the ratio of charge (e) to mass (m) for each particle i.e.

e/m is constant. The ratio e/m is constant not only on changing the gas but for any material used as cathode in discharge tube. This indicates that the nature of these particles are the same irrespective of the material used (i e. as cathode or as gas in the discharge tube) These negative particles are called *electrons* and are the essential constituent of all atoms.

4.1 3 Characteristics of electrons

(i) An electron carries a unit negative charge. The charge of an electron is 1.6 $X10^{-19}$ coulomb.

(ii) The mass of an electron is $9.108X10^{-28}$ g (1/1840 times that of a hydrogen atom).

4.1.4 Origin of positive rays

You know that matter and hence atom is electrically neutral. If an atom consists of electrons, then it must have an equal amount of positive charge also. The presence of positive charge in an atom was first shown by Goldstein by the following experiment.

Goldstein repeated Thomson's experiment with perforated cathode and observed some luminious rays passing through the holes of the cathode and moving in the direction opposite to cathode rays.

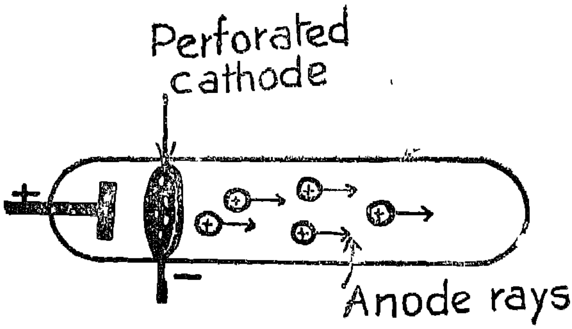

Fig. 4.6 Format on af Positive rays.

Under the influence of a strong electric or magnetic field, these rays were found to deflect towards negative field. This shows that these

rays are composed of positively charged particles. These rays are produced by removal of the electrons from neutral atom of the gas in the form of rays. Because of their positive charge these were called positive rays or the anode rays.

4.1.5 Characteristics of positive rays

(i) Like cathode rays, positive rays travel in straight lines.

(ii) They can produce mechanical effect (like cathode rays) and can ionise a gas through which they are passed.

(iii) The nature of positively charged particles depends upon the nature of the gas used in the discharge tube.

(iv) The charge (e) to mass (m) ratio (e/m) of positively charged particles is different for different gases and is very low as compared to this ratio for cathode rays.

These positively charged particles which constitute the positive or anode rays were called protons.

4.1.6 Characteristics of protons

(i) The mass of a proton is equal to the mass of a hydrogen atom.

(ii) The charge of a proton is equal in magnitude to the charge of an electron but it is opposite in sign.

4.1.7 Discovery of neutrons

Since the mass of an electron is negligibly small, the whole mass of an atom should be due to the mass of protons in it However, it was found true only for hydrogen atom. The masses of atoms of different elements could not be explained on this basis e.g magnesium (Mg) atom has 12 protons and its mass is 24.

Chadwick in the year 1931 gave a satisfactory explanation to this problem by proving the presence of a new particle in the nucleus of an atom in addition to protons. This new particle was called *neutron* Its mass is equal to that of proton Thus the mass of an atom of

magnesium is 24, because it contains 12 protons and 12 neutrons in it.

4.1 8 Characteristics of neutron

(i) The mass of a neutron is equal to that of a proton.

(ii) Neutron is neutral i.e it carries no charge.

Questions

1. Taking Thomson's and goldstein's experiments as clue, can you explain the presence of charges on the following ;
   (a) Presence of positive charge on glass rod when it is rubbed with silk ?
   (b) Presence of negative charge on ebonite rod, when it is rubbed with cat fur ?
2. Distinguish between cathode rays and positive rays.
3. What are the three fundamental particles of an atom ? Compare their properties ?

4 2 Discovery of Nucleus

Rutherford's Experiment

In an experiment, Rutherford bombarded a very thin gold foil with α particles α-particles are nothing but doubly charged helium ions (He^{2+}) i e a helium atom from which its 2 electrons have been removed. It was observed that :

(a) Most of the α-particles passed through the gold foil without deviating from their path. From this it was concluded that most of the space inside the atom is empty.

(b) Some of the α-particles deflected from their path. This indicated that the positively charged particles an of atom occupy a very little space.

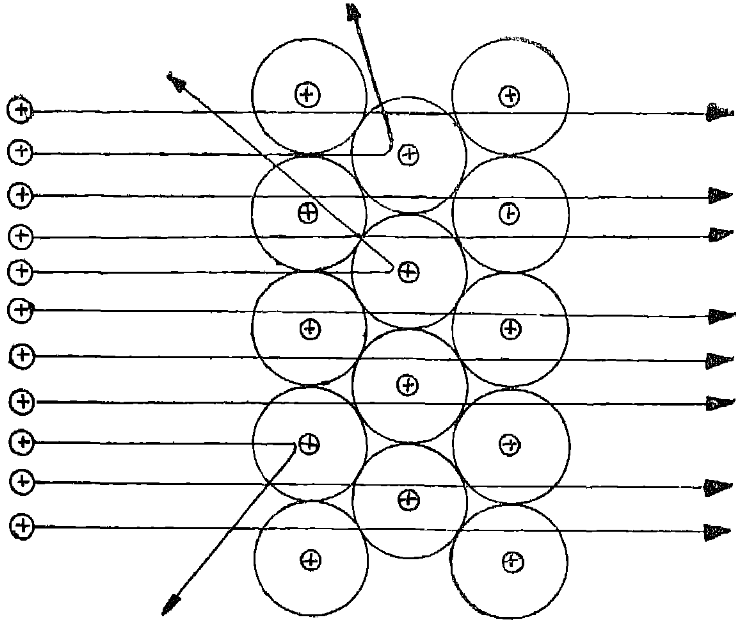

Fig. 4.7 Deflection of α-particles by a gold foil.

4.2.1 Rutherford's model of atom

On the basis of his experiment, Rutherford put forward the nuclear model of an atom :

(i) there is a positively charged centre in an atom known as nucleus. The mass of the atom is due to the mass of nucleus only.

(ii) the electrons are around the nucleus.

(iii) the size of nucleus is very small as compared to the size of an atom.

4.2.2 Drawbacks of Rutherford's model of atom

Due to the electrostatic force of attraction between an electron and the positively charged nucleus, the electron will be attracted by the nucleus. It should finally merge into the nucleus. If this is so, the atom should be highly unstable. But this is not true. We know that an atom is quite stable.

To Overcome this objection, Rutherford suggested that electrons are revolving constantly around the nucleus. The force of attraction between the moving electron and the nucleus is counter balanced by the centrifugal force of electrons (When a particle moves in a circle, it experiences a force in a direction away from the centre. This is known as centrifugal force) But when charged bodies move in circular motion, they emit radiations. This emission of radiation causes loss in the energy of the electron The electron will come closer and closer to the nucleus and will finally merge into the nucleus. This could not be explained by Rutherford's atomic model.

4.3 Bohr's Model of Atom

In order to explain the objections raised for the Rutherford's model, Bohr in 1913 gave the following postulates about an atom.

(i) The electrons revolve around the nucleus in a fixed circular path known as orbit.

(ii) An electron revolving in a particular orbit has fixed energy. These orbits are also called energy levels.

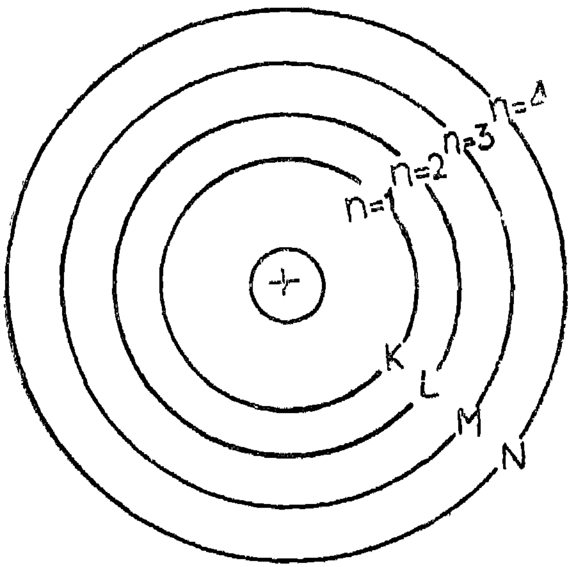

Fig. 4.8 Energy levels in an atom.

(iii) These orbits are represented by letters K, L, M, N — or numbers 1, 2, 3, 4, —.

(iv) An electron revolving in a particular orbit can move to another orbit by a gain or loss of energy.

4 4. Distribution of electrons in different orbits

The distribution of electrons in different orbits of an atom was suggested by Bohr and Bury. Following rules are followed for writing the number of electrons in different energy levels :

(i) The maximum number of electrons present in an atom is shown by the formula $2n^2$ where n is the orbit number or energy level. Hence the maximum number of electrons in

1st Orbit or K- shell will be $=2 \times 1^2=2$ electrons

2nd Orbit or L- shell will be $=2 \times 2^2=8$ electrons

3rd Orbit or M- shall will be $=2 \times 3^2=18$ electrons

4th Orbit or N- shell will be $=2 \times 4^2=32$ electrons

(ii) The maximum number of electrons in the outermost orbit will be 8 and in the penultimate orbit (next to outermost) will be 18

The orbits are also known as shells. The arrangement of electrons in different shells around the nucleus of an atom is known as electronic configuration. Thus if an atom contains 15 electrons, these will be present in orbits as follows,

K	L	M	N
2	8	5	

Table - 4.1

Composition of atoms of the first twenty elements

Element	Atomic number	Mass number	Number of protons	Number of neutrons	Number of electrons	Electronic configuration K	L	M	N
Hydrogen	1	1	1	—	1	1	—	—	—
Helium	2	4	2	2	2	2	—	—	—
Lithium	[illegible]	7	3	4	3	2	1	—	—
Beryllium	4	9	4	5	4	2	2	—	—
Boron	5	11	5	6	5	2	3	—	—
Carbon	6	12	6	6	6	2	4	—	—
Nitrogen	7	14	7	7	7	2	5	—	—
Oxygen	8	16	8	8	8	2	6	—	—
Fluorine	9	19	9	10	9	2	7	—	—
Neon	10	20	10	10	10	2	8	—	—
Sodium	11	23	11	12	11	2	8	1	—
Magnesium	12	24	12	12	12	2	8	2	—
Aluminium	13	27	13	14	13	2	8	3	—
Silicon	14	28	14	14	14	2	8	4	—
Phosphorus	15	31	15	16	15	2	8	5	—
Sulphur	16	32	16	16	-16	2	8	6	—
Chlorine	17	35	17	18	17	2	8	7	—
Argon	18	40	18	22	18	2	8	8	—
Potassium	19	39	19	20	19	2	8	8	1
Calcium	20	40	20	20	20	2	8	8	2

Questions

1. What are the salient features of Rutherford model of an atom ?
2. What were the objections made to Rutherford model ?
3. What postulates were given by Bohr to overcome the drawbacks of Rutherford's model of atom ?
4. Give the maximum number of electrons which can be present in different orbits.

4.5 Composition of first twenty elements

Atomic number

The number of net positive charge or number of protons in the nucleus of an atom is called atomic number. For example, sodium (Na) atom contains 11 protons in its nucleus. Hence the atomic number of Na atom is 11

Mass number

The sum of protons and neutrons present in the nucleus of an atom is knwon as mass number. For example, (Na) has 11 protons and 12 neutrons in its nucleus. Hence Mass number of Na=11 protons +12 neutrons =23.

On the basis of the knowledge given to you so far regarding atomic number, mass number, number of protons, electrons, neutrons and distribution of electrons in different orbits of an atom, the composition of atoms of first 20 elements from atomic number 1 to 20 can be written by you. This composition is given in *Table-4.1* for your comparision.

Questions

1. Explain the terms : (a) atomic number and (b) mass number.
2. Write electronic configuration of the elements with atomic numbers 11, 14 & 18.
3. Fill in the blanks :

Mass number	Atomic number	Number of protions	Number of neutrons
19	9	—	—
32	16	—	—

4.6 Valance electrons

We have already studied the distribution of electrons of first twenty elements in orbits. We can see from electronic configuration that the number of electrons in the outermost shell goes on increasing from 1 to 8 with increasing atomic number. These electrons in the outermenst shell take part in chemical reactions and are known as valence electrons.

Thus Na_{11} = 2,8,1 has one valence electron.

Cl_{17} = 2,8,7 has seven valence electrons.

Questions

1 How many valence electrons are present in the atoms of elements having atomic numbers 12,16 and 20 respectively ?

Isotopes

In nature, a number of such elements have been identified which have the same atomic number but different mass number For example, different forms of hydrogen have mass numbers 1,2 and 3 It is represented as H_1^1, H_1^2 and H_1^3*. This is due to the difference in the number of neutrons in them. H_1^1 contains only one proton whereas H_1^2 and H_1^3 contain 1 & 2 neutrons respectively in addition to one proton. Due to this difference in the composition of nucleus, they are identified as different substances. H_1^2 is also known as deuterium, symbol D, whereas H_1^3 is called tritium, symbol T. Such atoms which have the same atomic number but different atomic masses are called isotopes. Chlorine occurs in nature in two isotopic forms with atomic masses 35 and 37. Since they are present in the ratio 3:1, the atomic mass of naturally occurring chlorine is found to be 35.5.

$$\left(35.0 \times \frac{75}{100} \times 37 \times \frac{25}{100}\right) = \left(35.0 \times \frac{3}{4} + 37.0 \times \frac{1}{4}\right)$$

$$= \frac{105\ 0 + 37\ 0}{4} = \frac{142}{4} = 35.5\ )$$

*The atomic number and mass number of an atom is written in a symbolic form as follows; the symbol of the atom is written first. The atomic number is the subscript while mass number is the superscript. For example, sodium, at. No. 11 and mass No. 23 is represented as Na_{11}^{23}.

Questions

1. Which one of the following is a correct statement. The isotopes of an element have :

   (i) different electronic configuration

   (ii) same atomic number

   (iii) same atomic mass

   (iv) different number of protons.

2. Fill in the blanks :

   The atoms of the same element with same————————number but different———————number are called——————.

3. Composition of the nuclei of two atomic species X and Y and given as under.

X		Y	
Protons	= 6	Protons	= 6
Neutrons	= 6	Neutrons	= 8

Give the mass number of X and Y. What is the relation between the two species ?

IV Home Assignment

1. Suggest an experiment (other then those given in this unit) to prove that matter is electrical in nature.

2. Gases do not ordinarily conduct electricity. But in Thomson's experiment an electric discharge has been used as a source. How can you explain this fact ?

3. In Goldstein experiment, different values of e/m are obtained with different gases in the discharge tube. Why ?

4. What led Chadwick to think of the fundamental particle: neutron ?

5. In what respect is Bohr's model an improvement of Rutherford atomic model ?

6. Atomic number is a fundamental property of an element. Elaborate this statement with justification.

7. No two elements have identical electronic configuration. Justify the statement with examples ?

V. Self Assessment

1 It has been observed by you that when dry hair are combed, the comb gets charged. What happens to hair ?

2. Goldstein repeated Thomson's experiment with a perforated cathode. What is the importance of perforation in this case ?

3 Relate the observations of Rutherford's experiment with the conclusions drawn by him ?

4. What is the main difference between Rutherford's model and Bohr's atomic model ?

5. The atomic number of an element 'X' is 19 Its mass number is 39. Calculate the number of electrons, protons and neutrons in it ?

6. Write down the electronic configuration of the following elements: beryllium (At. No.4), phosphorus (At. No 15), fluorine (At. No.9).

7. "Carbon has four valence electrons in its atom". What does this statement tell you ?

Teacher's Guide

In order to understand chemistry, it is necessary to understand the architecture of atoms and molecules. Atoms and molecules are made up of electrically charged particles. In other words, matter is, in its ultimate nature, built up of electrical charges. The basic nature of matter may be discussed with everyday experiences. For example,

1. Combing of dry hair - There is a way our hair is often attracted to comb.
2. Rubbing of glass rod with silk and ebonite rod with fur.
3. Heating and lighting effects observed in certain materials when electricity is passed through them.

The model of atom may be developed on the basis of the characteristics of electric charges. The electrical nature of matter may be explained using the model of atom.

In Goldstein experiment, the meaning of perforation and the reason for using perforated cathode may be explained. The reason for different values of e/m for different gases may also be explained,

Rutherford's experiment may be discussed in the class. The conclusions based on the observations of this experiment may be drawn in order to evolve a nuclear model of atom.

Some of the descripencies existing in Rutherford's model of the atom were removed by Bohr's model. These descripencies may be discussed in the class.

The fractional atomic mass of atoms may be explained on the basis of isotopes.